

On the Result of Crossing Round with Wrinkled Peas, with Especial Reference to their Starch-Grains

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*On the Result of Crossing Round with Wrinkled Peas, with
Especial Reference to their Starch-grains.*

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One of the characters with which Mendel dealt in his hybridisation experiments with peas was, as is well known, the shape of the ripe seed. Weldon, in his criticism* of Mendel's interpretation of his results, showed that round were not discontinuously distinct from wrinkled peas, but that intermediate shapes connecting these two extremes were not infrequently exhibited. The answer which was made to Weldon's criticism was that the intermediate shapes were due to spurious pitting or dimpling of the seed, and did not represent an intermediate condition of the germ which gave rise to them. And this answer was shown to be correct by the work of Gregory,† who found that the starch-grains of round and wrinkled peas were quite distinct, and that they afforded an infallible test by which the real character of a pea with doubtful shape could be determined.

Our knowledge of this subject has not advanced beyond the stage reached by Gregory in 1903; that is to say, we know no more about the inheritance of wrinkledness and roundness than Mendel did, except that each of these two characters is associated with a particular kind of starch-grain. What is the nature of the starch-grain in the hybrid; and how the characters of the starch-grains segregate, if they do so at all, in subsequent generations, are points on which we are at present ignorant. The observations, which I have to record, form the first instalment of an attempt to fill up this gap in our knowledge.

Part of the cost of these experiments was defrayed by a Government Grant.

The Starch-grains of the Round Pea.

The grains in a round pea such as "Eclipse" are, as shown in fig. 1,‡ single, potato-shaped grains. They will be referred to for the sake of brevity as *p*-grains. Their average length is 0.0322 mm., their average breadth

* 'Biometriska,' vol. 1, p. 231.

† 'The New Phytologist,' vol. 2, No. 10, p. 226.

‡ Fig. 1 is magnified slightly less than figs. 2 and 3. The actual sizes of the types of grains figured is given in the text. All the grains described have been derived (as far as possible) from the *deeper* layers of the cotyledon as distinguished from the *superficial* ones where the grains are smaller.

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0.0213 mm. These measurements are accurate to 2μ . The length-breadth index (*i.e.*, $100 \times \text{breadth-length}$) is 66.14. The above figures were calculated from a series of measurements of 232 grains.

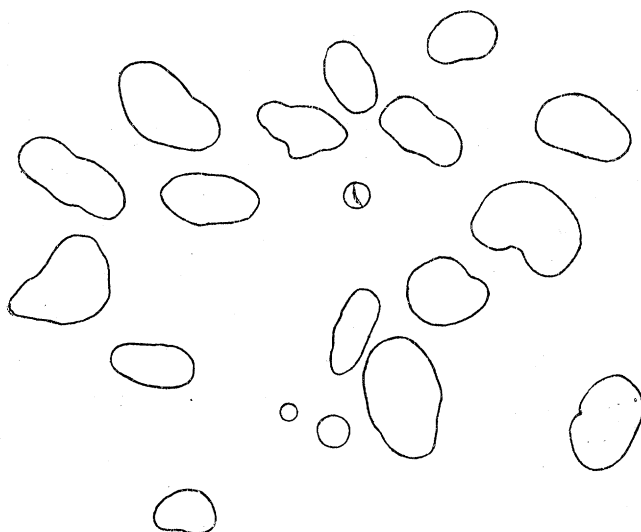


FIG. 1.—Starch-grains of Round Pea (*p*-grains).

Beside the large potato-shaped grains which have just been described there are always found associated with them extremely few very much smaller grains which are *round*. Two of these are shown in fig. 1. These small round grains occasionally exhibit traces of division, as in the case of the third small grain shown on fig. 1. The division does not affect the contour of the grain and I have not found a small grain divided into more than two subdivisions.

The Starch-grains of the Wrinkled Pea.

The starch-grains in a wrinkled pea like "British Queen" are, as shown in fig. 2, immediately distinguishable from those of the round pea, by the fact that they are compound. They will be referred to for the sake of brevity as *c*-grains. Each grain consists of a number of pieces which varies between 2 and 8. The separate pieces are loosely held together by a refringent yellow substance which, from the fact that it does not stain blue with iodine, appears to be of a different nature from the pieces themselves.

These grains are very liable, as Gregory pointed out, to break up into their component pieces. I do not propose to go into the question of the relation between the number of component pieces and the size of a grain. Suffice it to say that the examination of a large number of samples reveals a rough

positive correlation between size of grain and number of component pieces. The commonest types of grains are those with 4, 5 or 6 component pieces. Grains with 7 or 8 pieces are rarer; grains with 2 or 3 pieces are intermediate in frequency between those with 4, 5 and 6 on the one hand and 7 and 8 on the other. But whilst grains with 7 or 8 pieces are not much larger than those with 4, 5 or 6, grains with 2 or 3 are always conspicuously smaller than those with 4, 5 or 6.

The average length of the grains is 0.0269 mm., the average breadth 0.0248 mm. The average length-breadth index is 92.19; that is to say, the grains are, as a glance at fig. 2 shows, almost round. The above figures were calculated from measurements of 105 grains.

There are also in wrinkled peas a number of very small single grains which can be distinguished from the pieces, into which the compound grains break up, by the fact that they are circular. They are always smaller than grains consisting of two pieces. Two of them are shown in fig. 2.

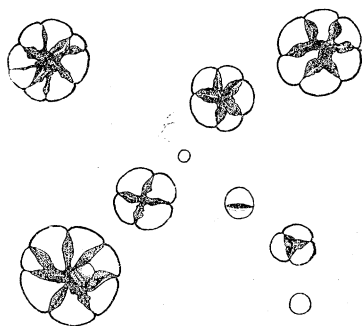


FIG. 2.—Starch-grains of Wrinkled Pea (c-grains).

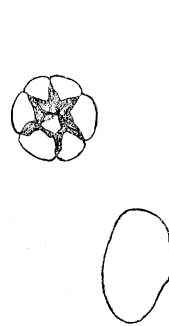


FIG. 3.—Normal c-grain of Wrinkled Pea, together with occasional p-grain.

Lastly, I have found very rarely indeed, in examples of "British Queen," isolated *p*-grains, as shown in fig. 3. At first I thought these grains had been introduced by using a razor with which I had been cutting round peas. But after taking every precaution to guard against this, by immersing the razor in strong potash before using it, I still found them: so that I cannot but believe that they really occur in wrinkled peas. I have also found them "Telephone," and in extracted wrinkleds.

The Starch-grains of the Hybrid.

For the examination of the characters of the grains of F_1 cotyledons I had, unfortunately, only two seeds left from a number of crosses between "British Queen" and "Eclipse" which Mr. J. T. Wadsworth made for me in the summer of 1905.* All the rest had been sown: the plants bearing the F_3 cotyledons raised from them are now in flower.

The starch-grains in the F_1 cotyledons produced by crossing a round with a wrinkled pea are not like those of the round pea, as might have been expected from the fact that round is dominant over wrinkled, but are intermediate between those of the round and those of the wrinkled pea.

In the first place they are nearly round (see fig. 4), and will on this account and for brevity's sake be referred to as *r*-grains.

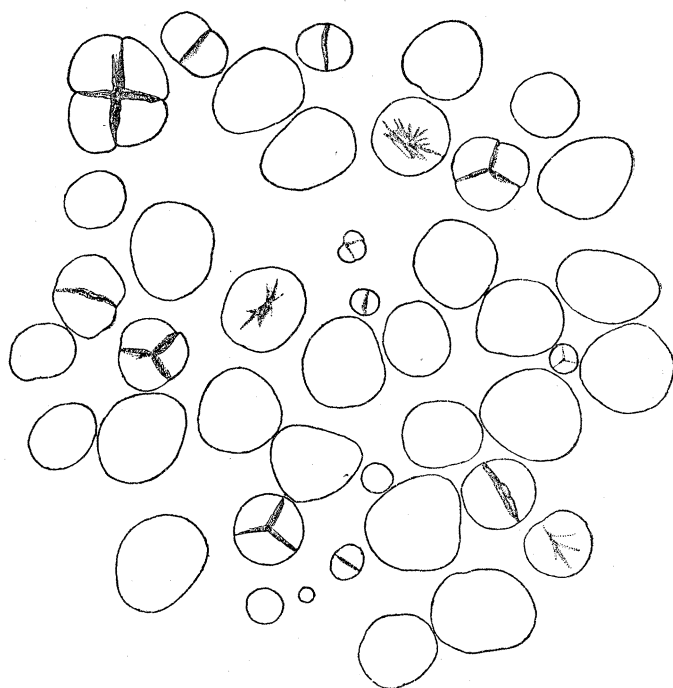


FIG. 4.—Starch-grains of F_1 cotyledons (*r*-grains).

In the second place, whilst the majority of the grains in the F_1 seeds are single the remainder are compound. In a count of 579 grains, 356 were single, 223 were compound. In the third place the degree of compoundness exhibited by the compound grains in F_1 seeds is intermediate between

* For the nature of the starch grains in other crosses between round and wrinkled peas, see pp. 132, 133.

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singleness and the degree of compoundness in the grains of wrinkled peas. For whilst in these latter the number of pieces varies between 2 and 8 and the commonest is 6, in the F_1 grain it varies between 2 and 4 and the commonest is 3.

Table I gives the average length, breadth, and length-breadth index of 166 r -grains, side by side with the measurements for p - and c -grains for comparison.

Table I.

	Round.	F_1 .	Wrinkled.
	p -grain.	r -grain.	c -grain.
Average length	0·0322	0·0276	0·0269
Average breadth	0·0213	0·0236	0·0248
Length-breadth index	66·14	85·5	92·19

This table shows that, in the matter of shape, the F_1 grain is intermediate between the p - and the c -grain, but *nearer the c -grain*.

The Starch-grains in a Subsequent Generation.

I have not at present any information as to the nature of the grains in F_2 , but I have some data relating to F_5 which throw much light on the mode of segregation in this case.

By a fortunate chance I happened, when I turned my attention to this subject, not to have sown the contents of 48 packets of F_5 peas,* each separate packet of which contained five seeds from a single plant. Thirty-six of the packets contained round seeds; 12 of them contained wrinkled ones. I possessed a record of the number of green and yellow, as well as, what concerns us now, the number of round and wrinkled seeds produced by each

* The history of these seeds is as follows: In the spring of 1905, Mr. C. C. Hurst kindly gave me the seeds borne on an F_3 plant from a cross which he had made between "British Queen" (yellow wrinkled) and "Eclipse" (green round) ('Journ. R. Hort. Soc.,' vol. 28, pp. 3 and 4). These seeds included yellow rounds (Y R), yellow wrinkled (Y W), green rounds (G R), and green wrinkleds (G W). I sowed these four sorts separately. The Y R's gave either (i) plants bearing only Y R's, or (ii) plants bearing Y R's and Y W's, or (iii) plants bearing Y R's and G R's, or lastly (iv) plants bearing Y R's, Y W's, G R's, and G W's. The total number of yellow seeds, round and wrinkled, borne by plants falling in the last category (iv) was 232. These were sown, and 196 of them produced mature plants. 10 seeds from each of the 196 plants thus raised were preserved, in 2 packets of 5 from each plant. All of these seeds were sown this spring, except the contents of the 48 packets referred to in the text.

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of the plants, five of each of whose seeds were preserved in the packets. So that I could find out in the case of the seeds in any given packet whether they were borne on a plant which produced only rounds, or both rounds and wrinkleds, or only wrinkleds. I wish particularly to emphasise the fact that this information was not written on the packets, but was obtainable by looking up, in the records, the plant represented by the number on the packet containing its seeds.

I started by writing down the catalogue-numbers of each of the packets. Then I recorded the nature of the grains in the seeds opposite the number of the packet containing them. Not until I had examined all the grains did I refer to my records for the characters (whether D D, D R, or R R in respect of seed shape) of the parent plants of the seeds in the packet.

I postponed this reference to my records until after all the grains had been examined, in order to prevent any possibility of the determination of the nature of the grains being influenced by a knowledge of the gametic constitution of the plant which bore them.

Our interest centres chiefly on the possible difference between the round peas borne on plants bearing both round and wrinkled, and those borne on plants bearing only round. I shall, therefore, postpone reference to the contents of the 12 packets containing wrinkled peas until after I have dealt with the rounds.

There were 36 packets containing round seeds. In every case—16—in which all the five seeds in a packet contained nothing but potato-shaped grains (and occasionally the very small compound grains found in “Eclipse”) the plants bearing them had produced only round seeds. Table II gives the details of these families, and fig. 5 shows the appearance of these extracted dominant grains.* It will be seen that they do not differ sensibly from the *p*-grains of “Eclipse.”

The small compound grains, which are often exceedingly minute, are likely to be overlooked: the absence of any record of them in the first four families in Table II may be due to the fact that I did not detect them because I was not on the look-out for them. The presence of these grains in a pea is indicated in the table by the letters *fc*. There was a single case (54.129.ii) of an apparently compound large *p*-grain divided longitudinally into two; but the rarity of such a grain points to the conclusion that this case was due to an accidental fracture; which would be quite likely to occur during the scraping of the soaked pea with a razor.

* I have not measured any grains in F_3 . But no difference could be seen, between the *p*-, *c*-, and *r*-grains in this generation and the grains, of these three types, already described.

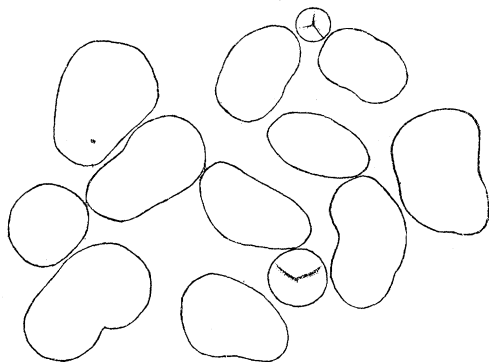


FIG. 5.—Starch-grains of DD Round Peas in F_5 .

Table II.

Catalogue- number of parent-plant.	Number and characters of seeds borne by parent-plant.				Character of samples of seeds examined for starch- grains.	Nature of starch-grains in each of these seeds.				
	Colour.		Shape.			i.	ii.	iii.	iv.	v.
	Y.	G.	R.	W.						
54. 13	31	13	44		5 round	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>
54. 17	27	14	38		"	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>
54. 25	32	15	47		"	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>
54. 50	20	8	28		"	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>
54. 60	23	11	36*		"	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>p f c</i>
54. 64	20	4	24		"	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>
54. 83	19	11	30		"	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>
54.104	31	14	45		"	<i>p f c</i>	<i>p</i>	<i>p f c</i>	<i>p</i>	<i>p</i>
54.117	40	8	48		"	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>p f c</i>
54.129	30	15	45		"	<i>p</i>	<i>p †</i>	<i>p</i>	<i>p</i>	<i>p</i>
54.161	15	7	22		"	<i>p f c</i>	<i>p f c</i>	<i>p f c</i>	<i>p f c</i>	<i>p f c</i>
54.172	128	41	169		"	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>
54.175	17	4	21		"	<i>p</i>	<i>p f c</i>	<i>p f c</i>	<i>p f c</i>	<i>p f c</i>
54.184	16	8	22		"	<i>p f c</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>
54.190	13	6	19		"	<i>p</i>	<i>p</i>	<i>p</i>	<i>p f c</i>	<i>p</i>
54.191	24	11	35		"	<i>p f c</i>	<i>p f c</i>	<i>p f c</i>	<i>p f c</i>	<i>p f c</i>

p signifies potato-shaped grain.

fc signifies the additional presence of the small compound grains found in "Eclipse," in very small numbers.

* When a discrepancy occurs in Tables II, III, and IV between the totals for cotyledon colour and totals for shape in a given plant, it signifies that in the case of some of the seeds of that plant the shape was determinable whilst the colour was dubious, or *vice versa*.

† A large double grain in this pea.

In every case in which at least one of the five seeds in a packet contained either a round or an irregular round grain, the plants bearing them had produced both round and wrinkled seeds. That the category irregular round

is not due to a difficulty to distinguish between *r*- and *p*-grain—even if it were possible for anyone familiar with these grains to have this difficulty—is shown by the fact that all peas containing grains falling into this category were borne by heterozygote plants, *a fact which was not known when the grains were being examined.* Table III gives the details of these families and fig. 6 shows some of the *r*-grains.

Table III.

Catalogue- number of parent-plant.	Number and characters of seeds borne by parent-plant.				Character of sample of seeds examined for starch- grains.	Nature of starch-grains in each of these seeds.				
	Colour.		Shape.			i.	ii.	iii.	iv.	v.
	Y.	G.	R.	W.						
54. 3	28	4	22	9	5 round	<i>r sc</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>r sc</i>
54. 18	20	9	17	6	"	<i>r sc</i>	<i>p</i>	<i>r sc</i>	<i>r sc</i>	<i>r sc</i>
54. 19	31	12	31	12	"	<i>p</i>	<i>p</i>	<i>r sc</i>	<i>p</i>	<i>p</i>
54. 23	26	6	22	6	"	<i>r mc</i>	<i>r mc</i>	<i>r mc</i>	<i>r mc</i>	<i>r mc</i>
54. 33	26	10	26	9	"	<i>i</i>	<i>r mc</i>	<i>r mc</i>	<i>r mc</i>	<i>p fc</i>
54. 52	33	13	30	13	"	<i>i sc</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>r sc</i>
54. 57	23	8	21	10	"	<i>i sc</i>	<i>i sc</i>	<i>i sc</i>	<i>i sc</i>	<i>i sc</i>
54. 65	20	3	15	8	"	<i>p</i>	<i>r fc</i>	<i>p</i>	<i>i sc</i>	<i>p</i>
54. 77	30	9	35	2	"	<i>p</i>	<i>r fc</i>	<i>r fc</i>	<i>r fc</i>	<i>p</i>
54. 89	32	9	29	8	"	<i>r sc</i>	<i>i fc</i>	<i>r sc</i>	<i>p</i>	<i>r sc</i>
54.105	32	8	27	13	"	<i>i mc</i>	<i>i mc</i>	<i>r mc</i>	<i>r mc</i>	<i>i mc</i>
54.112	27	6	16	5	"	<i>p</i>	<i>i fc</i>	<i>p</i>	<i>p</i>	<i>p</i>
54.121	19	4	21	2	"	<i>p</i>	<i>p</i>	<i>r mc</i>	<i>p fc</i>	<i>p fc</i>
54.146	15	4	14	5	"	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>r mc</i>
54.150	18	6	17	7	"	<i>r sc</i>	<i>r sc</i>	<i>p</i>	<i>p</i>	<i>p</i>
54.177	26	7	25	8	"	<i>r mc</i>	<i>r sc</i>	<i>r sc</i>	<i>r sc</i>	<i>r sc</i>
54.179	37	4	38	2	"	<i>i fc</i>	<i>i mc</i>	<i>p fc</i>	<i>p fc</i>	<i>r mc</i>
54.180	36	11	38	9	"	<i>p</i>	<i>p fc</i>	<i>i fc</i>	<i>p fc</i>	<i>p fc</i>
54.181	38	9	36	11	"	<i>r sc</i>	<i>r sc</i>	<i>p fc</i>	<i>r sc</i>	<i>i fc</i>
54.182	37	9	30	13	"	<i>r fc</i>	<i>r fc</i>	<i>i fc</i>	<i>r fc</i>	<i>r fc</i>

r = round grains (fig. 6).
i = irregular round.
sc = some compound.
mc = many compound.
 Other symbols as in Table II.

The difference between peas marked *r mc* and those marked *r fc* is sometimes very great. A count of 508 grains from a pea marked *r mc* revealed 203 compound and 305 single. Whilst in a pea marked *r fc*, there were only 28 *c*-grains in 304 counted.

In the absence of any information as to the behaviour of the characters of the grains in F₂ it is not possible to make any definite statement as to the mode of segregation in this case; but the following points seem to be clear. We have seen that the grain in the F₁ seed is round. The evidence points to the fact that the heterozygote round peas in subsequent generations are characterised by the possession of *i*- or *r*-grains and homozygote rounds by

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p-grains. For, in the first place, no round grains appeared in 80 seeds from 16 plants which bore only round seeds. In the second place, of the 100 round seeds borne by plants bearing both round and wrinkled, 40 had *p*-grains as against the 33 or 34 expected by my theory—a discrepancy not so great that it cannot be accounted for by the smallness of the number of seeds.

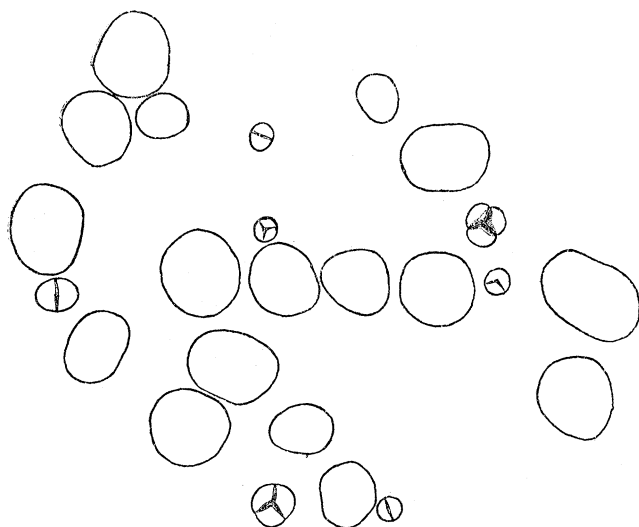


FIG. 6.—Starch grains of DR Round Peas in F_5 .

If the association of *r*-grains with heterozygote round, and of *p*-grains with homozygote round holds good for the F_2 generation, we have a means of distinguishing between $D D$ round and $D R$ round in F_2 ; instead of, as at present, having to wait until their progeny are mature in the following year.

A further point is demonstrated by the nature of the grains in F_1 , and borne out by those in F_5 . It is that the shape of the grain is inherited separately from its composition—if we may use this term to cover the singleness or compoundness of the grain. In the round pea the grains are single and long; in the wrinkled they are compound and round; in the hybrid they may be either single or compound, but are more round than long. In a subsequent generation, F_5 , we have *r*-grains exhibiting much compoundness (54.23) and others exhibiting little (54.182 i, ii, iv, and v). We have (possibly) *p*-grains either with no compounds, or with few; and intermediate grains either with few compounds (54.179 i) or with many (54.179 ii).

The wrinkled peas contained, as was to be expected, *c*-grains, but some of them contained in addition, very sparingly, *p*-grains, one of which is shown in fig. 7.

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In the case of one plant, only one of the five seeds examined exhibited them. In the case of two other plants, two out of the five seeds exhibited them, and in the case of both these plants the five seeds had been noted, before soaking, as being only *rather* wrinkled.



FIG. 7.—Example of occasional *p*-grain occurring, in extracted Wrinkled Pea in F₂.

The details of the grains and parentage of the wrinkled seeds are shown in Table IV.

Table IV.

Catalogue- number of parent-plant.	Number and characters of seeds borne by parent-plant.				Characters of samples of seeds examined for starch- grains.	Nature of starch-grains in each of these seeds.				
	Colour.		Shape.			i.	ii.	iii.	iv.	v.
	Y.	G.	R.	W.						
54. 38	24	7		32	5 <i>wr.</i>	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>
54. 55	30	8		38	"	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>
54. 59	18	3		21	"	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>
54. 61	19	2		21	"	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>
54. 66	27	3		30	"	<i>c</i>	<i>c</i>	<i>c sp</i>	<i>c</i>	<i>c</i>
54. 87	16	3		19	"	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>
54. 97	32	12		41	5 rather <i>wr.</i>	<i>c</i>	<i>c sp</i>	<i>c sp</i>	<i>c</i>	<i>c</i>
54.113	14	3		17	5 <i>wr.</i>	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>
54.127	11	8		19	"	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>
54.138	30	15		45	"	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>
54.140	24	6		30	"	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>
54.187	13	7		20	5 rather <i>wr.</i>	<i>c</i>	<i>c sp.</i>	<i>c</i>	<i>c sp</i>	<i>c</i>

c = compound grains.
sp = some *p*-grains.

The Amount of Water absorbed by the Seed on germination in the Various Generations in the Preceding Experiment.

Gregory's statement that, according to Denaiffe, "wrinkled seeds take up more water on germination than do round seeds," made me curious to find out how *much* more water wrinkled seeds take up than round; and, having determined this, to find out what relation the hybrid bore to its two parents with regard to this character.

I propose to refer to the capacity for taking up water as the absorptive capacity; and the measure which I shall use throughout of this capacity is

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the amount of water, taken up by a pea immersed in tap-water for 24 hours expressed as a percentage of the weight of the dry pea. The average absorptive capacity of 15 “British Queen” (*i.e.*, wrinkled) peas weighed separately is 122 per cent. The average absorptive capacity of 12 “Eclipse” (*i.e.*, round) seeds is 86 per cent. The absorptive capacity of a single F₁ seed, produced by crossing “British Queen” with “Eclipse,” is 100 per cent. It will be seen that the hybrid is intermediate between the two parents.

The only evidence I have concerning the absorptive capacity in succeeding generations is derived from the examination of the contents of two sample pods in the F₂ generation derived from the cross (already referred to) between “British Queen” and “Eclipse,” made by Mr. Wadsworth. The facts are shown in Table V. And it will be seen that whilst the difference between the absorptive capacity of round and wrinkled is well marked, that the absorptive capacities of the two kinds of rounds, *i.e.*, those with *p*-grains and those with *r*- or *i*-grains, is not in accordance with expectation. For in the pure round pea the *p*-grain is associated with an absorptive capacity 86, and in the F₁ round the *r*-grain with one of 100. And it was not unreasonable to suppose that the absorptive capacity was in some way determined by or, at any rate, associated with the nature of the grain rather than with the shape of the seed, for it is in seed-shape only that we find dominance; whilst in both grain-shape and absorptive capacity the two parent forms blend.

The expectation, however, suggested by this parallel between starch-grain and absorptive capacity in F₁ is not, as we see, fulfilled in F₂.

Table V.

Pod.	Individual seeds.	Colour and shape of seed.	Nature of grains.	Absorptive capacity.
89 19 16i	<i>α</i>	GR	<i>p</i>	96
	<i>β</i>	YR	<i>p mc</i>	100
	<i>γ</i>	GR	<i>p</i>	97
	<i>δ</i>	YW	<i>c</i>	141
	<i>ε</i>	GW	<i>c</i>	141
89 12 19ii	<i>α</i>	YR	<i>r mc</i>	100
	<i>β</i>	GR	<i>r mc</i>	97
	<i>γ</i>	YR	<i>p</i>	97
	<i>δ</i>	YR	<i>i mc</i>	97
	<i>ε</i>	YW	<i>c</i>	142
	<i>ζ</i>	GW	<i>c</i>	139

The r-grains in other Hybrid Peas.

The intermediate nature of F₁ grains was also observed in the following crosses (Table VI). The grains in these seeds were not measured; but it was

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evident, at a glance, that the grains were more round in some cases than in others. Thus, M 303 and M 313 had the most conspicuously round grains that I have seen in F_1 seeds.

Table VI.

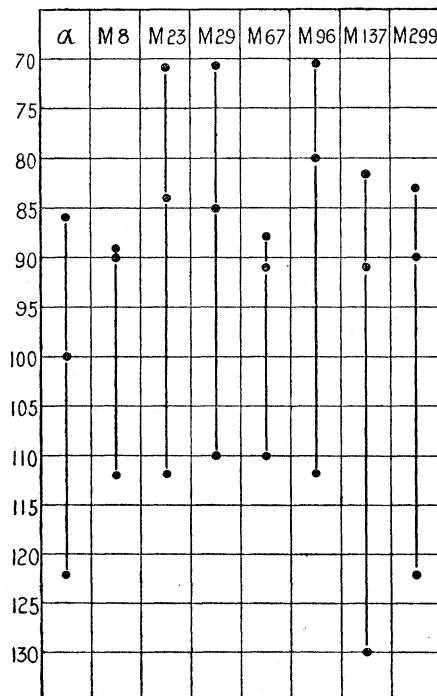
Catalogue-number of cross.	Number of seeds examined.	Pistil-parent.	Pollen-parent.
M 299	2	"British Queen"	Maple from Mr. R. H. Lock.
M 303	1	"	Grubb, corn dealer, Oxford
M 312	1	"	Zucker Erbse. rotbl. kron.*
M 313	3	"	"
M 316	1	"	Maple from Mr. R. H. Lock.

* A maple sugar pea with pink flowers and "mummy" (*i.e.*, fasciated) habit. Bought from Messrs. Haage und Schmidt, Erfurt, Germany (No. 1286, p. 24 in 1907 Catalogue).

The Absorptive Capacity in other Hybrids.

The absorptive capacity of the F_1 seed, as well as that of its two parents, was determined in eight cases altogether, one of which is "British Queen" by "Eclipse," to which reference has already been made. The results are shown on Table VII. The numbers at the left of the table refer to the absorptive

Table VII.



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capacity. The uppermost dot in a column gives the absorptive capacity of the round parent in a cross: the lowermost dot, that of the wrinkled parent; and the intermediate one, that of the hybrid. The absorptive capacity is, in every case, except in that of the round parent in M 299, calculated from weighings made with the actual variety of round or wrinkled pea utilised in the cross; and, indeed, in many cases from the seeds from the very plant which served as mother or father. Instead of the absorptive capacity of the actual round parent in M 299 is written the average of the values for the five different varieties of round peas we have dealt with.

Table VIII gives the parentage of the crosses summarised in Table VII.

Table VIII.

Catalogue-number of cross.	Wrinkled parent.	Number of seeds weighed.	Round parent.	Number of seeds weighed.	Number of seeds of hybrid weighed.
^a	♀ British Queen	15	♂ Eclipse	12	1
M 8	♀ Laxton's Alpha (Haage & Schmidt)	5	♂ Sangster's No. 1.....	4	1
M 23	♀ " "	5	♂ Yellow round* (Genoa)	9	1
M 29	♀ Laxton's Alpha (Sutton)	8	♂ " "	9	1
M 67	♀ " "	8	♂ Bohnenerbse† (Haage & Schmidt)	3	1
M 96	♂ Laxton's Alpha (Haage & Schmidt)	5	♀ Yellow round (Genoa)	9	6
M 137	♀ Telephone (Haage & Schmidt)	3	♂ <i>Pisum arvense</i> ‡ <i>hibernicum</i>	6	1
M 299	♀ British Queen	15	♂ Maple from Mr. R. H. Lock	<i>vide text</i>	2

* Plants grown from (evidently unimported) yellow seeds which I bought in a small shop in Genoa.

† A large, long pea with a black hylum, which, however, is not situate in the middle of one side as in the bean, but at the end.

‡ *Pisum arvense hibernicum* is a small pea seldom attaining 2 feet in height, though it is not dwarf in habit, sold by Messrs. Haage and Schmidt (No. 1660, p. 30, 1907 Catalogue). Its seeds can be sorted into four categories. Maple and purple spots on grey; maple on grey; purple spots on grey, and grey. *Vide* "Report II to Evolution Committee of Royal Society," and R. H. Lock, 'Roy. Soc. Proc.,' B, vol. 79, *supra*, p. 28.

Summary.

My investigations on this subject are being continued. The facts so far brought to light are:—

1. That, although roundness is dominant over wrinkledness in peas, the starch-grain of the F₁ generation (the round or *r*-grain—fig. 4) is a blend between the type of grain of the round pea (the potato-shaped or *p*-grain—

fig. 1) and the type of grain of the wrinkled pea (the compound or *c*-grain—fig. 2), in respect of three characters—

- (a) It is intermediate in shape as measured by its length-breadth index—that of the *p*-grain being 66, that of the *c*-grain 92, and that of the *r*-grain 85 (neglecting decimals).
- (b) It is intermediate in the distribution of compoundness, inasmuch as some of the *r*-grains are compound and some single.
- (c) It is intermediate in the degree of compoundness, inasmuch as amongst those *r*-grains which are compound the most usual number of constituent pieces is three, whereas in *c*-grains it is six.

2. In a subsequent generation— F_5 —the homozygote round peas contain *p*-grains; the heterozygote round peas contain *r*- or intermediate grains. But both *r*- and intermediate grains may be associated either with a high, or with a low degree of compoundness.

3. *P*-grains occasionally occur in wrinkled peas in F_5 , and the evidence (Table IV, 54.97 and 187) suggests that the existence of these grains in wrinkled peas tends to make them less wrinkled.

4. A wrinkled pea takes up more water when it germinates than a round one. The hybrid between a round and a wrinkled pea is intermediate in respect of this character between its two parents.

5. But this intermediateness of the hybrid in absorptive capacity is not occasioned by the intermediateness of the starch-grain of the hybrid, because, in F_2 , peas containing *r*-grains and peas containing *p*-grains both have the same absorptive capacity as the F_1 pea (see Table V).

6. When, therefore, we cross a round with a wrinkled pea, we are dealing with *four* separately heritable characters:—

- (i) The shape of the pea—whether round or wrinkled.
- (ii) The absorptive capacity of the pea—whether low or high.
- (iii) The shape of the starch-grain—whether long or round.
- (iv) The constitution of the starch-grain—whether single or compound.

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